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PROVISIONAL SPECIFICATION FOR THE INVENTION ENTITLED

"A CONTROL SYSTEM"

The present invention will be described in the following statement:

TITLE

"A CONTROL SYSTEM"

The present invention relates to a control system, in particular a system for use with machinery having moving parts, such as press brakes, to detect the presence of an obstruction in the path of the moving part and control the movement of the part accordingly.

A typical break press has a long anvil with a V-shaped groove along the top and a blade with a forward edge that fits into the groove of the anvil. To bend a piece of sheet metal, most machines drive a back-gage into a position to align the material. The material is placed onto the anvil and may be slotted into guides provided by back-gage clamps. The operator then activates the press, driving the blade down so that it comes into contact with, and then bends the sheet metal that has been placed over the groove of the anvil.

After the bend, the material can be difficult to remove from the anvil if the blade has not been set to retract far enough away from the work. For this reason, a press brake blade is often configured to retract to a height where the bent material can easily be removed, and a new piece placed onto the anvil. Opening the blade to a set height in this fashion reduces productivity as the operator must wait for the blade to first retract and then approach the next piece of material that is placed onto the anvil in response to activation of an approach switch.

The large opening increases danger to the operator as there is a larger gap into which the operator may insert fingers or hands. Techniques such as having a programmable blade opening height for each stage of the bending process and/or a very fast

approach speed to the material (with lasers projected along the underside of the blade for safety) have been used to improve productivity.

A number of systems have been devised to detect the presence of hands or fingers under the blade and to therefore avoid the possibility of entrapment. For example, a system using laser beams projected along the underside of a blade may be used for this purpose and to improve productivity by permitting the blade to travel straight through the mute point in relative safety. An improved method has also been described in the applicant's own earlier patent application, published under International Publication Number WO03/104711.

To improve safety, the blade may be stopped a preset distance (often called the mute or pinch point) above the material and the approach switch required to be released and re-asserted again before the bending action starts. This action reduces productivity as extra time is spent, during the process of aligning the material, activating the approach switch, waiting for the blade to approach the material and releasing and reasserting the approach switch at the mute point.

A further problem with existing press brakes arises when bending a box. During this operation. an operator may bend the two sides of the box then rotate the work piece 90 degrees to bend the back of the box. If the material isn't aligned correctly then the left or right edge of the blade could be damaged, or the material crumpled due to the blade coming into contact with one of the up-stands. This would be likely to occur if the material is not aligned correctly when the approach switch is activated.

In order to avoid this problem, it is known to use a laser system to make the blade stop just above the up-stands or configure such a stop into the machine, thereby permitting the operator to ensure the material is positioned correctly for the blade to pass between the sides without coming into contact with them. Such systems however will result in decreased productivity due to the additional time added to the process. Alternatively, the operator may lower the opening height of the blade to less than the height of the material upstands.

The present invention attempts to overcome at least in part some of the aforementioned problems.

In accordance with one aspect of the present invention there is provided a control system for use with a machine having a moving tool arranged to move through a known path of movement, the control system characterised by comprising:

a means for detecting the location of objects in or adjacent the path of the tool; and a processing and control means arranged to determine the distance between the objects in or adjacent the path of the tool and a leading edge of the tool;

wherein the control system includes at least one mode of operation in which the processing and control means controls movement of the tool such that the distance between the objects in or adjacent the path of the tool and the leading edge of the tool is maintained within predetermined minimum and maximum values.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a view of a typical press brake to which the control system of the present invention may be applied;

Figure 2 is a light emitting means and a light receiving means of a control system in accordance with the present invention;

Figure 3 is a perspective view of a press brake with a region around the tool edge illuminated in accordance with the present invention;

Figure 4 is a view of a shadow map created by the control system of the present invention;

Figure 5a is a top view of a light emitting means adjustment arrangement for use with the control system of the present invention;

Figure 5b is a side view of the light emitting means adjustment arrangement of Figure 5b;

Figure 6 shows an arrangement of various zones around the leading edge of the tool of the control system used to control movement of the tool;

Figure 7 is top view of a sheet of material to be bent into a box;

Figures 8a to 8c are views of the shadows cast on the light receiving means during the steps of the first two bends of the sheet of material of Figure 7;

Figure 9a to 9c are views of the shadows cast on the light receiving means during the steps of the third bend of the sheet of material of Figure 7;

Figure 10 is a front view of a press brake during the third bend as shown in Figure 9; and

Figure 11 is a perspective view of a press brake having a control system including a position detection means; and

Figure 12 is a flow diagram of the steps of movement of the tool of the press brake of a control system in accordance with the present invention;

Figure 13 is a flow diagram of the steps of movement of the tool of the press brake of a control system in accordance with a second alternative embodiment of the present invention;

Figure 14 is a flow diagram of the steps of movement of the tool of the press brake of a control system in accordance with a third alternative embodiment of the present invention; and

Figure 15 is a flow diagram of the steps of movement of the tool of the press brake of a control system in accordance with a fourth alternative embodiment of the present invention.

Referring to the Figures, there is shown a control system for use with machinery having moving parts to detect the presence of an obstruction in the path of the moving part. In the embodiment shown, the control system is employed on a press brake comprising a moving tool 12 arranged to strike work placed on an anvil 14.

Figures 1 to 3 show a control system of the type described in International Patent application published under International Publication Number WO03/104711, on which the present invention may be implemented. The control system requires a means for detecting the location of objects in or adjacent the path of the tool 12 and a processing and control means arranged to determine the distance between the objects and a leading edge 22 of the tool 12.

The control system 10 shown includes a light emitting means 16 and a light receiving means 18. The light emitting means 16 is arranged to illuminate a region 20 around a

portion of the path of movement of the tool 12 in order to detect obstructions in said region 20.

Figure 1 shows an arrangement in which a laser diode 23 and lens arrangement is used to create a large area parallel light beam 24. The light receiving means 18 includes a pinhole aperture 42 in a screen 44 and a charge coupled device (CCD) 46.

As shown in Figure 3, the light emitting means 16 is mounted at one end of the tool 12 of the press brake such that the parallel light beam 24 illuminates a region 20 around the path of movement of the tool 12 which includes the forward edge 22 of the tool 12. The light receiving means 18 is mounted at the opposite end of the tool 12 to receive the light beam 24. If an obstruction 50, such as the hand of the operator, enters the region 20, a corresponding shadow 52 will be cast on the CCD 46.

A processing and control means (not shown) is connected such that it receives information from the light receiving means 18 and controls operation of the press brake. The processing and control means may be in the form of a software program residing on a computer which receives input from the output of the light receiving means 18.

As described in the above mentioned International Patent application, the processing means captures the images received by the CCD 46 and stores the images as a shadow map 54. The processing means will store a plurality of known safe shadow maps 54 (referred to as a 'shadow stack'). The known safe shadow maps 54 are shadow maps 54 where no obstruction is detected that would require stopping or slowing of the press brake operation.

In a preferred embodiment, the control system includes a means to automatically adjust the direction of the emitted beam, as shown in Figures 5a and 5b. The direction

is altered by movement of three linear actuators 70. Moving the laser diode 23 towards or away from the lens arrangement 25 by moving all three linear actuators 70 together causes the laser beam to diverge or converge accordingly. Moving the linear actuators 70 independently, alters the direction of the beam. Preferably the movement of the linear actuators 70 is controlled by the processing and control means based on the image received by the light receiving means 18, thus allowing automatic alignment.

The control system of the present invention includes a number of modes of operation. The mode of operation in which the control system exists at any point in time will be determined by the images received by the light receiving means and input from the operator. The control system of the present invention includes at least one mode of operation in which the processing and control means uses the image received by the light receiving means 18 to determine the distance between the leading edge 22 of the tool 12 and any obstructions in the path of movement of the tool 12 such that the distance between the leading edge 22 of the tool 12 and the nearest point on the obstruction is maintained between predefined minimum and maximum values. That is, the tool 12 is arranged to follow movement of obstructions at a certain distance. This allows the operator to move the work without interference from the tool 12 and without the need to fully retract the tool 12.

Figure 5 shows an arrangement for zones around the tool 12 defined in the processing and control means for controlling movement of the tool 12 in the mode of operation described above. In the arrangement of Figure 5, there is included a first approach zone 80, a second approach zone 82, a stop zone 86 and a retract zone 88. In use, if an obstruction is detected by the processing and control means in the first approach zone

80 or no obstruction is detected, the tool 12 is moved toward the anvil 14. If the obstruction is detected in the second approach zone 82, the tool 12 is moved toward the anvil 14 at a speed slower than movement caused by obstructions in the first approach zone 80. If an obstruction is detected in the retract zone 88, the tool 12 is moved away from the anvil and if an obstruction is detected in the stop zone 86, movement of the tool 12 is halted. While this arrangement uses four zones, it will be appreciated that other arrangements would also be possible.

The control system would also generally have at least two other modes of operation, the second mode of operation being the bending of the work on the anvil and the third mode being retraction of the tool 12.

The change of mode of operation of the control system is controlled by images received or one or more operator input means. The input means many comprise an approach switch and a retract switch. The retract switch acts to move the tool 12 away from the anvil 14 when depressed. The movement of the tool 12 away from the anvil 14 ceases when the retract switch is released.

Activation of the approach switch acts to either cause the tool 12 to follow the work as described previously at a distance allowing the operator to adjust the material, or to approach the work prior to a bend, or to bend to work, depending on factors including whether the image received by the light receiving means is part of a known shadow map 54.

The use of the control system will now be described with reference to the bending of a box from the sheet of material 60 shown in Figure 7. The flow diagram of Figure 12 sets out one embodiment of the logic which may be used by the processing and control means during the steps of bending the box.

In order to best describe the operation, the tool 14 is retracted by the operator using the retract switch leaving ample room for the material to be placed on the anvil 14. Figure 8a shows the image of the tool 12 and anvil 14 with no material present. The operator then places the sheet of material 60 on the anvil 14 and activates the approach switch. The processing and control means controls movement of the tool 12 such that images that do not match any of the known safe shadow maps are kept a preset distance (approx 25mm in this case) from the tool (state 2 in the flow diagram). As there are initially no known maps, the tool 12 is moved until the anvil 14 and sheet of material 60 are approximately 25mm from the tool 12. While the approach switch is kept depressed, the processing and control means will maintain this state, thus following the movement of the work.

The tool 12 stops at the condition described above (state 2 in the flow diagram and as shown in Figure 8b) and the operator must release and then reassert the approach switch to continue, if deemed safe. The processes and control means then registers that the approach switch has been released (thus moving to state 3) and reasserted in a condition in which the tool is not more than the preset distance from the obstruction. As the image at this point is not a known safe shadow map, the tool 12 moves downwardly until the tool 14 comes to a predefined distance from the work or anvil, building a new shadow map (thus moving through state 5 to state 7). The predefined distance is a distance set to be sufficiently close to the work to continue the bend, for example 3mm. Preferably this movement is at a slow speed. The image received by the light receiving means 18 is now that shown in Figure 8c.

From this state, release and reassertion of the approach switch causes the tool 12 to bend the material (moving from state 7 to the next 'Stop' condition and on to state 9).

After the bend is complete, the newly created shadow map is saved to the shadow stack, the control system is returned to state 2 of Figure 12 and follows the material placed on the anvil by the operator.

In bending the second side of the box, the upstand will be sufficiently far from the illuminated region to not be detected. From state 2, the processing and control means determines that image is a known shadow map (built and stored when bending the first side) and therefore moves to state 4, thus moving at a faster speed until the tool is close to the anvil (state 6 via condition 13). The bend can then be performed by release and reassertion of the approach switch. Alternatively, after a predetermined time period, the bend can automatically commence (dashed line of condition 15).

To further describe the operation, we will assume that the operator retracts the tool 12 to well above the material. As described previously, in state 2, the tool 12 is maintained at a preset distance from unknown shadows. Therefore, when bending the third side, the upstand of the box is not recognised and therefore the top of the upstand is kept at the preset distance from the tool 12 (as shown in Figure 9a).

When the operator is ready to proceed, the approach switch is released and reasserted as above and the tool descends slowly to the predefined distance from the work or the anvil 14 (to state 7 as described previously). In this case, the tool 12 descends until it is at the predefined distance from the upstand (as shown in Figure 9b). On release of the approach switch in this case, the system moves from state 7 to state 3 via condition 11 as the tool 12 is not close to the anvil 14. On reassertion of the approach switch, the tool 12 descends slowly and the portion of the image which would obstruct the tool 12 is disabled as shown in Figure 9c (via state 5 to state 7 again). During this process, a shadow map is created as a known safe shadow map.

As the portion of the image obstructing the tool 12 is disabled, the tool 12 will descend until the tool 12 is the predefined distance from the work or anvil 14. In this case, the tool 12 descends until it is the predefined distance from the flat portion of the work on the anvil 14 as shown in Figure 9c as no other obstructions exist. The bend can then be completed and the known safe shadow map saved to the shadow stack as described previously by release and reassertion of the approach switch after the tool 12 is sufficiently close to the anvil 14.

After completing the third bend, the tool 12 retracts and the control system returns to state 2 in which the material is followed for as long as the approach switch remains asserted. The operator turns the material around. The tool 12 will move until it is the predefined distance from the top of the unknown image, which in this case will be the upstands created by the first and second bends. By releasing and reasserting the approach switch twice, the control system will move through states 5 and 7 to bend the material, as described previously in relation to bending the third side. Alternatively, if the approach switch has been released before the tool has retracted to be higher than the upstand or the tool opening was set lower than the upstand, then the approach switch would only need releasing and reasserting once.

When the operator requires to bend a further box of the same type, the process will be faster due to the systems ability to recognise the images matching the shadow maps stored during bending the first box. On bending each side, the system will recognise the image as being one of the stored shadow maps and therefore progress through state 4. A single release and reassertion in the case of each side would allow the bend to be completed. Preferably, the maximum height for the tool is appropriately set and confirmation time outs are used, then as per condition 15, the control means confirms

safety allowing the approach switch to be asserted once and remain asserted when bending all sides of subsequent boxes.

Figures 13 to 15 show three further embodiments of logical processes of a system in accordance with the present invention. These embodiments are variation of the system described in to Figure 12 and can be understood with reference to that embodiment.

The embodiment shown in Figure 13 is very similar to the embodiment shown in Figure 12. The main difference is that after the following process (state 2) when the tool has stopped ("waiting for approach sw" state), asserting the approach switch, in the case that the shadow map is not known and the tool is close to the material, results in the tool slowly descending until it is close to the anvil, rather than stopping on each obstruction (that is returning via condition 11 in Figure 12). The tool is set to move slowly during this descent to be considered safe.

Figure 13 shows an alternative embodiment in which the tool is arranged to follow movement of the obstructions without the approach switch being asserted. The system is arranged such that the tool follows the obstructions at a first relatively long distance if the shadow map is unknown (state 3) and descends to a relatively close distance (state 4) if the shadow map is known. If in state 4, the approach switch is asserted and the tool is close to the anvil, the system will allow the bend to proceed (via condition 9 to "check if ok to proceed" and to state 6). If at any other time the approach switch is asserted, the system will move to state 2, in which the tool will slowly approach the material, stopping at new obstructions and saving new shadow maps until the tool is close to the anvil and the bend may proceed.

Figure 14 is an alternative embodiment that uses a follow mode (state 2) but which does not use saved shadow maps. In this embodiment, the tool is maintained a preset

distance above the obstructions. The tool will stop at this distance when no movement of the obstructions occurs and be in state 9. From this state, if the approach switch is reasserted, the tool will either approach and bend the material if the tool is close to the anvil (that is move to state 5) or portions of the tool close to the image will be disabled (state 4) and the system will return to state 2 (that is following the obstructions).

Figures 10 and 11 show a further aspect of the present invention. As described previously, a problem arises when bending a side of a box between two upstands, as shown in Figure 10. If the work is not aligned correctly along the length of the anvil 14, it is possible that the tool 12 may strike one of the upstands. In accordance with this further aspect of the invention, a position sensing means 66 is provided on the press brake. The position sensing means 66 is located relative to the back-gage clamps 15 such that the position sensing means can determine if the work in not correctly positioned within the clamps.

The position sensing means may comprise one or more inductive sensors which can determine whether the work is covering some or all of the sensing means. The output of the sensing means is then used to determine whether the work is correctly positioned prior to the bend.

Modifications and variations as would be apparent to a skilled addressee are deemed to be within the scope of the present invention

DATED THIS 9TH DAY OF AUGUST 2004.

KEVIN STEPHEN DAVIES
By his Patent Attorneys
LORD & COMPANY
PERTH, WESTERN AUSTRALIA.

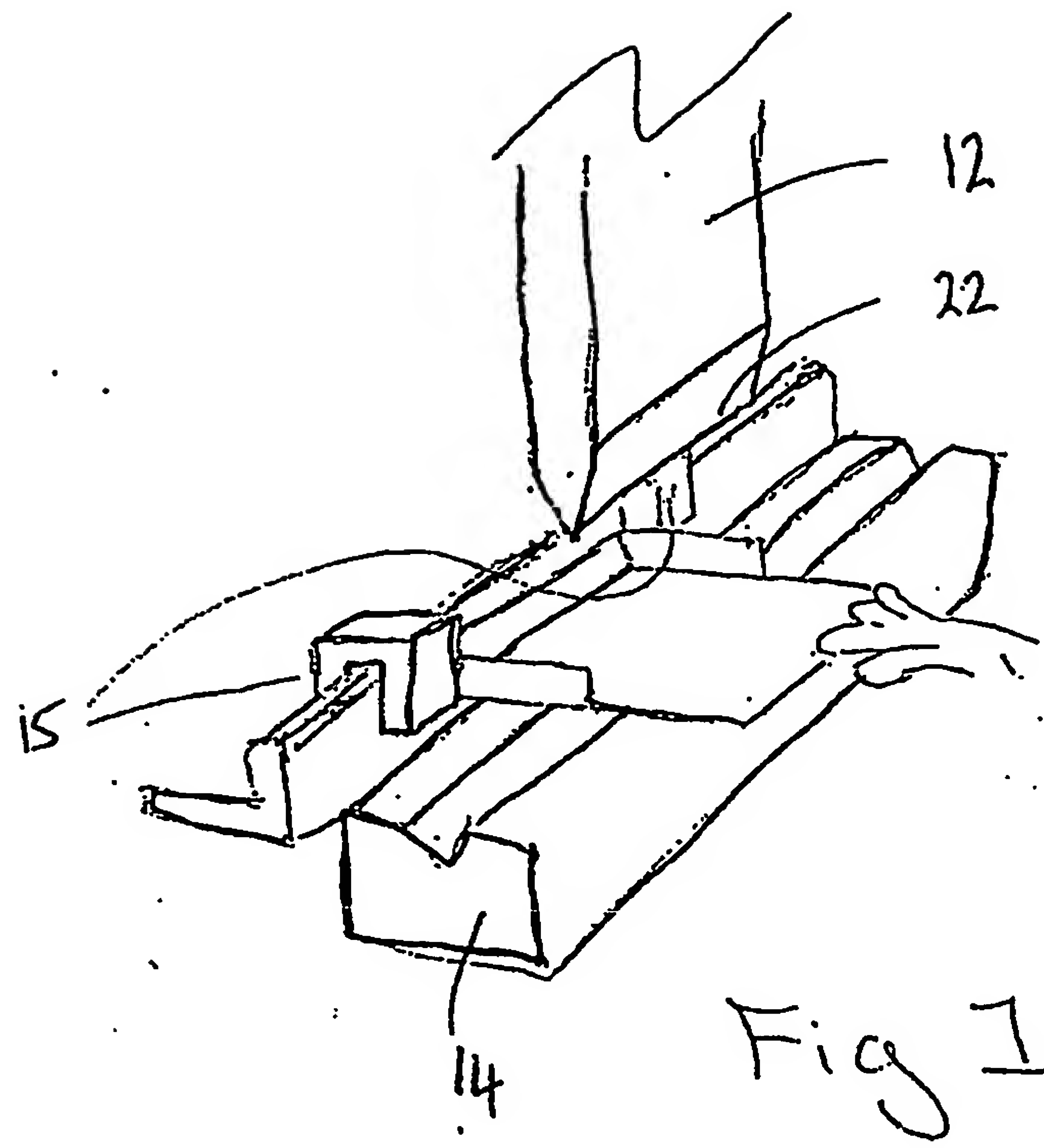


Fig 1.

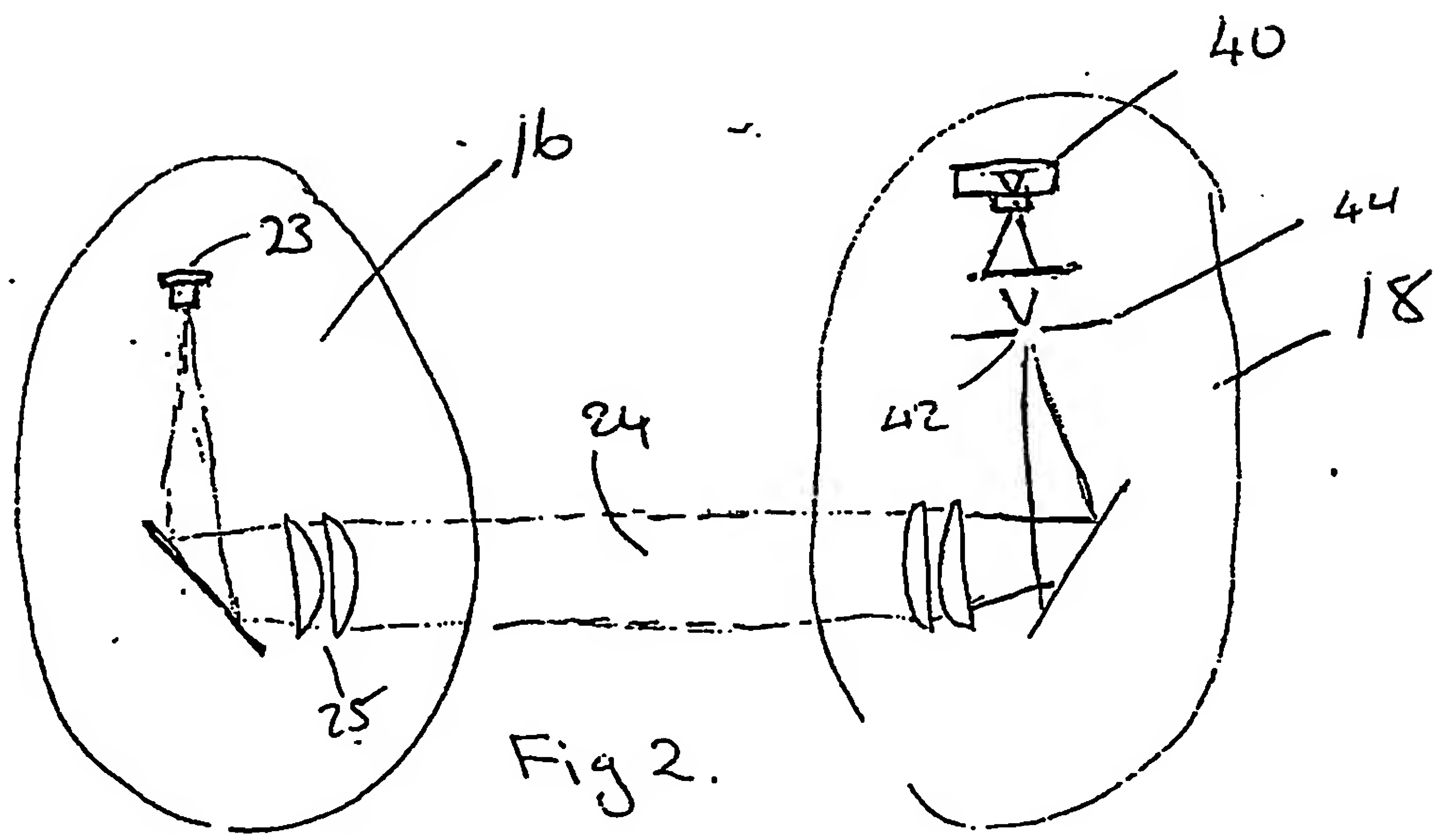


Fig 2.

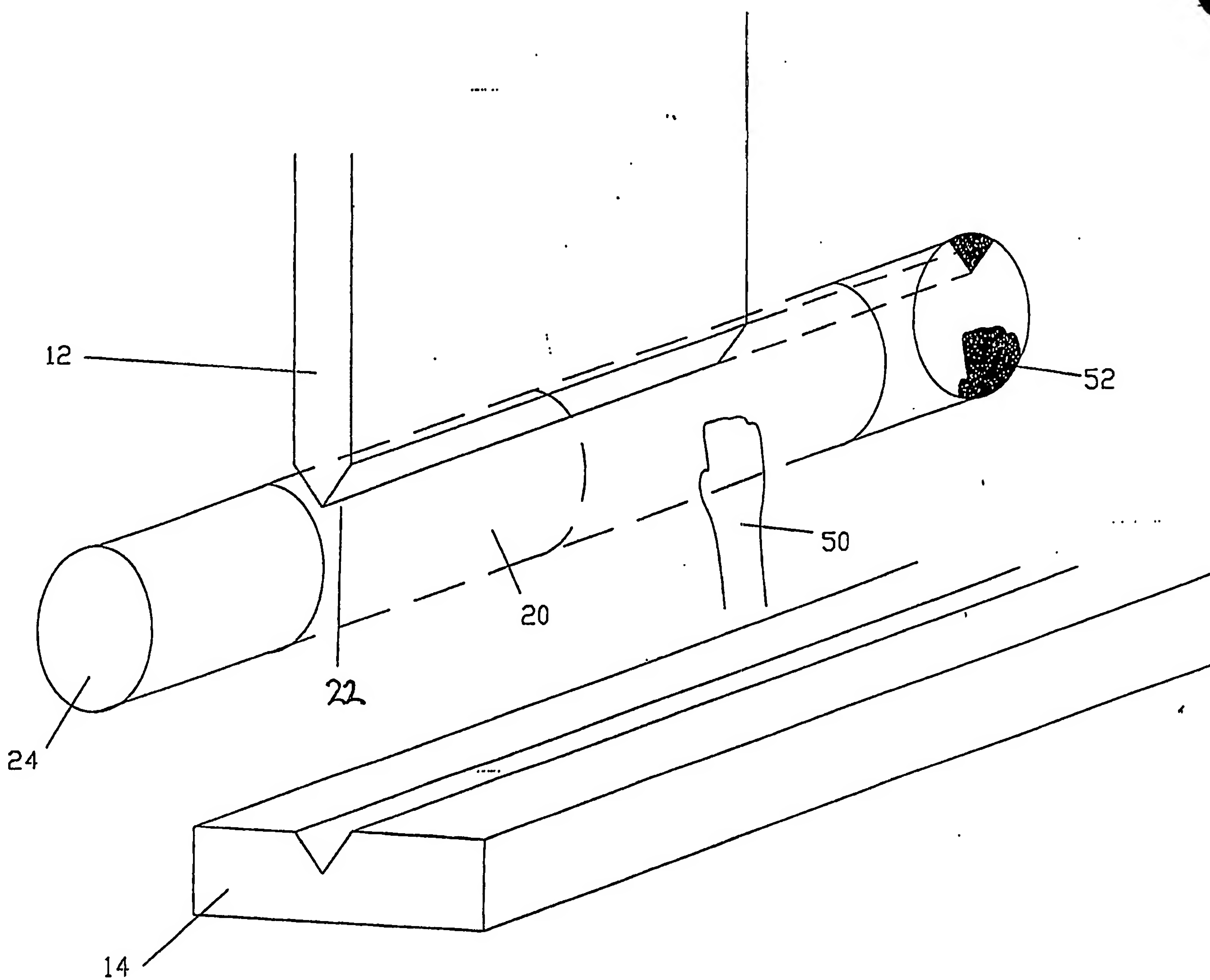


Fig 3

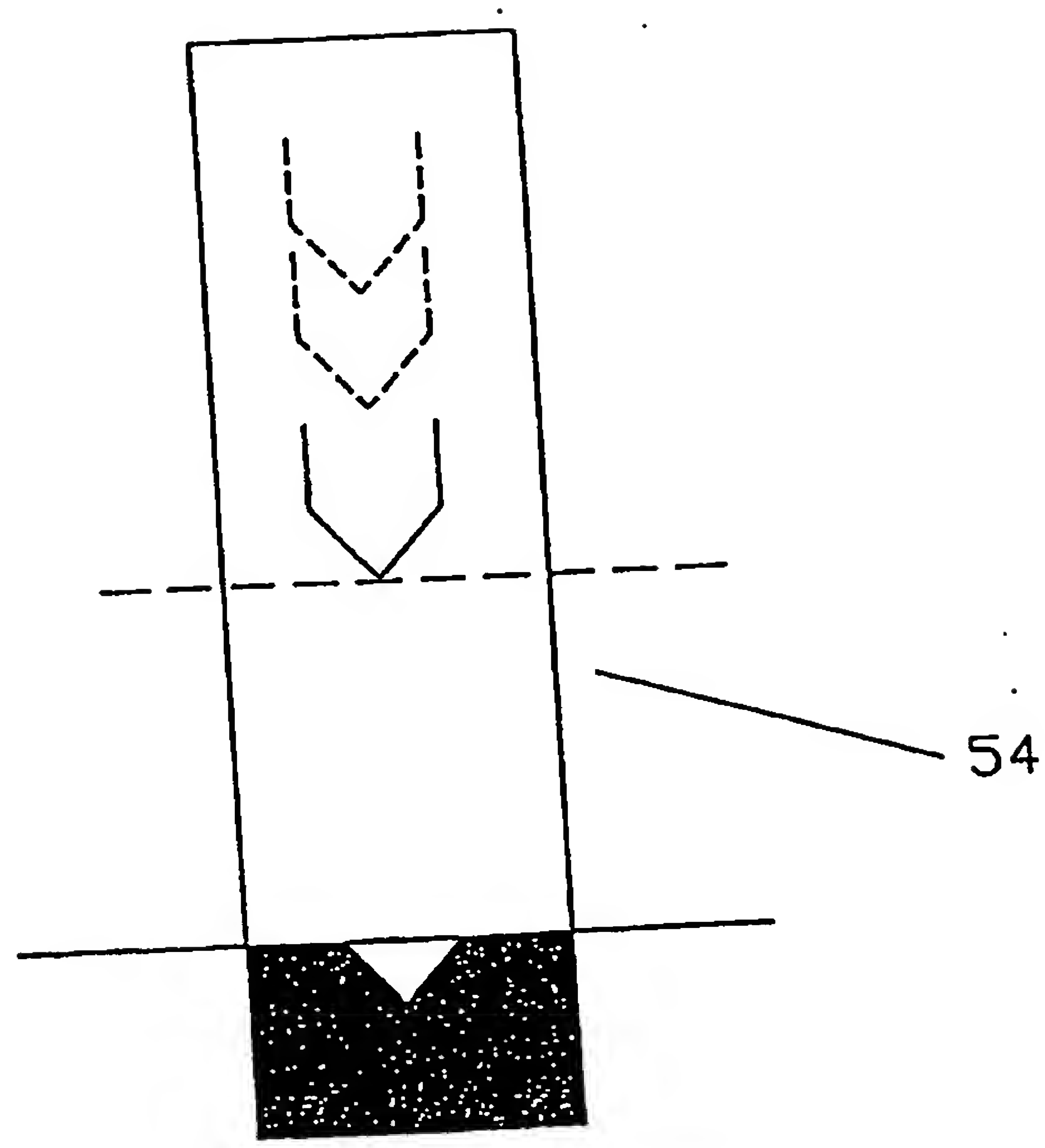


Fig 4

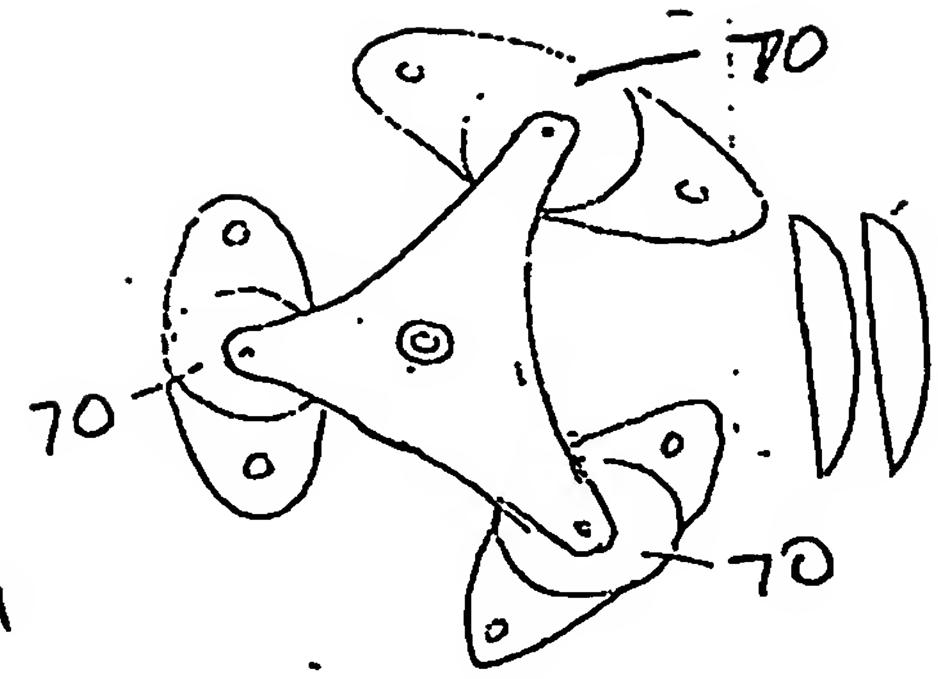


Fig 5a

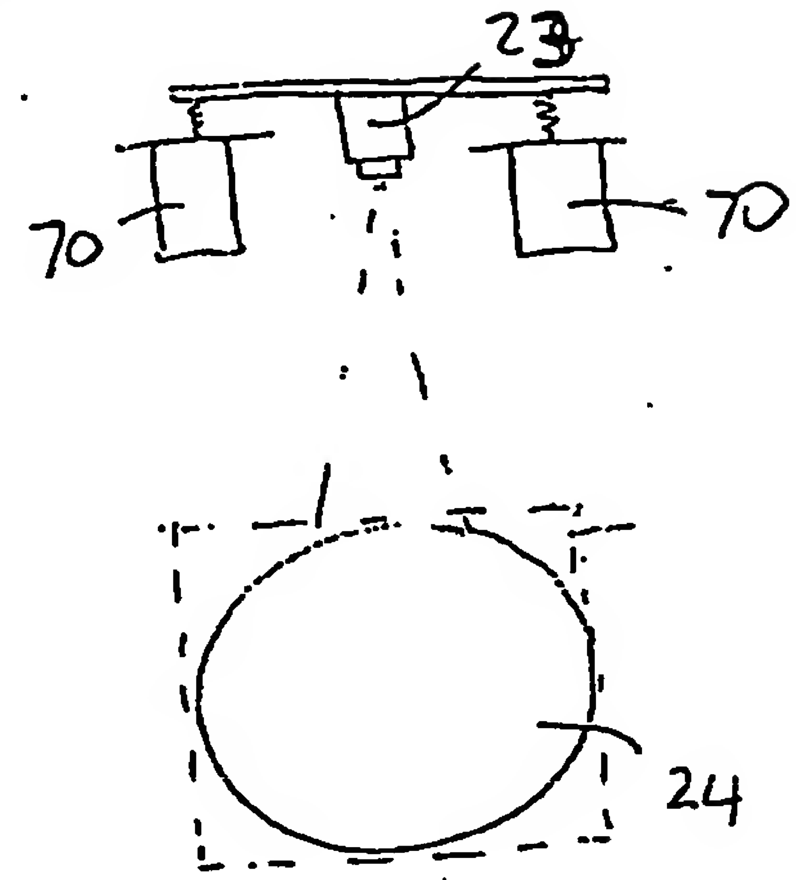


Fig. 5b

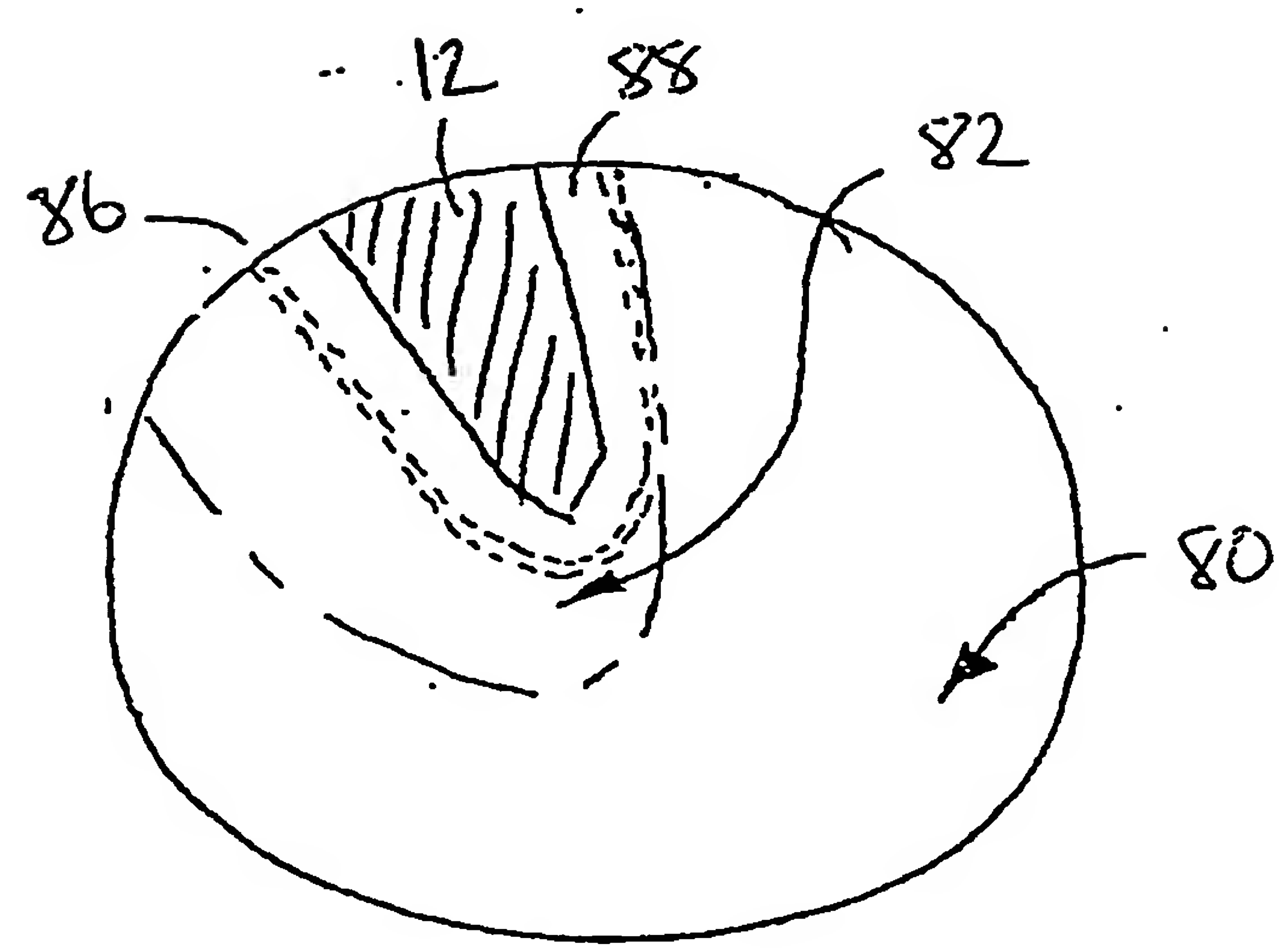


Fig 6

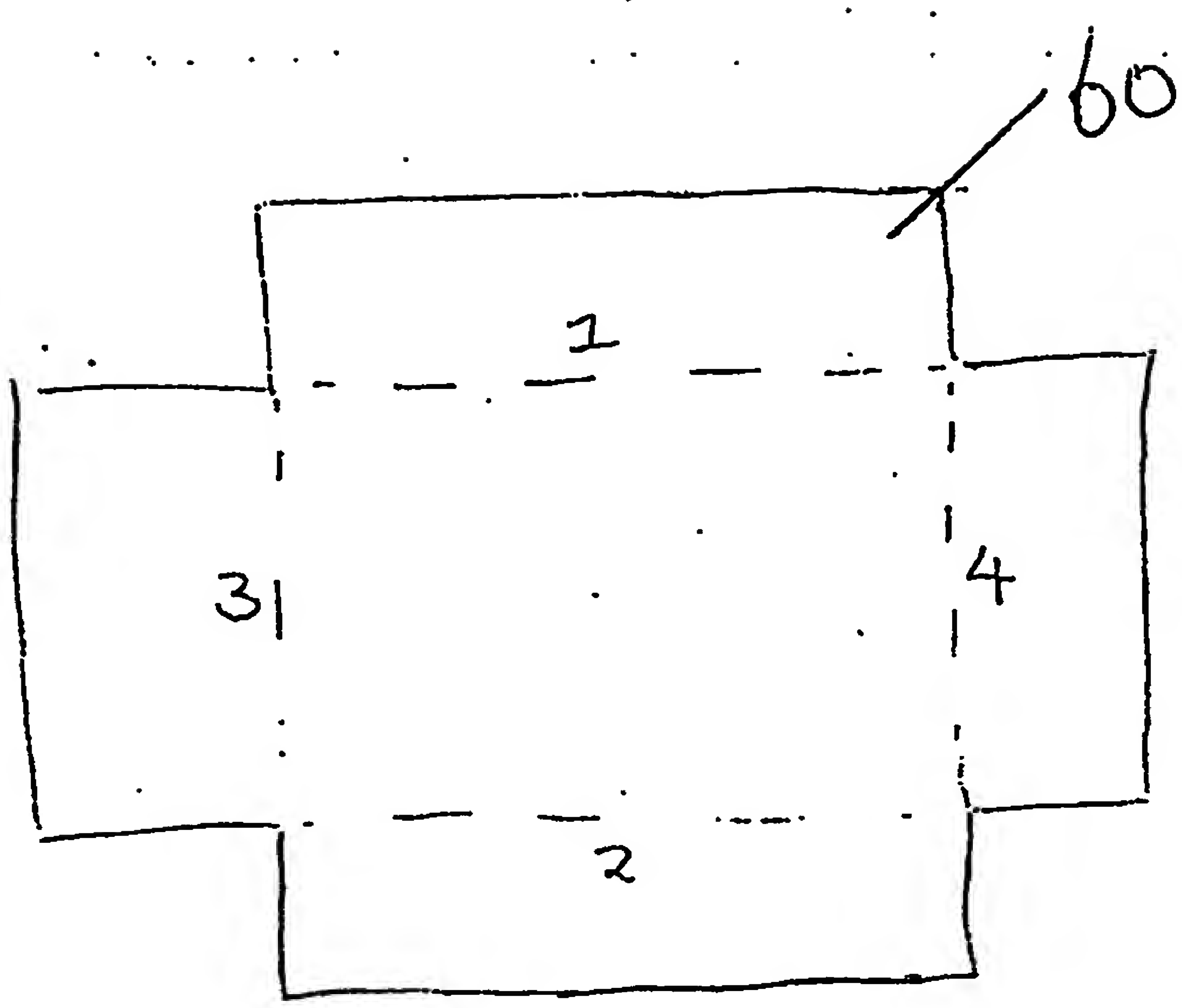


Fig 7

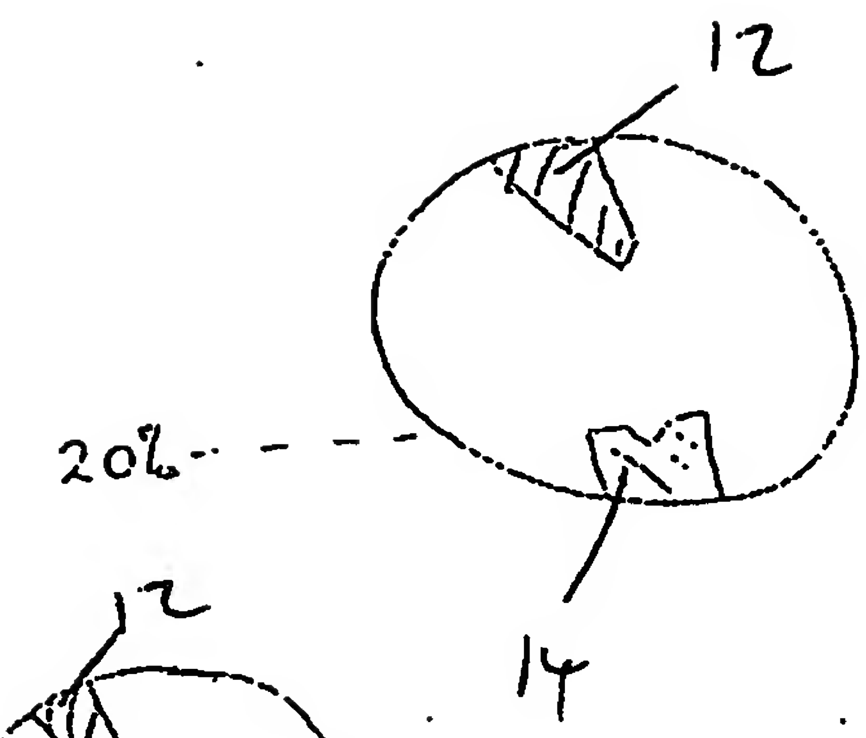


Fig 8a

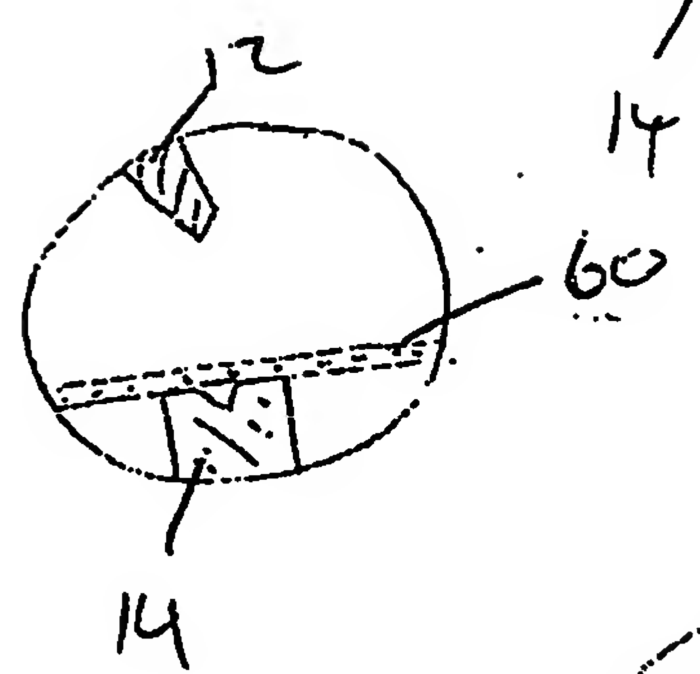


Fig 8b

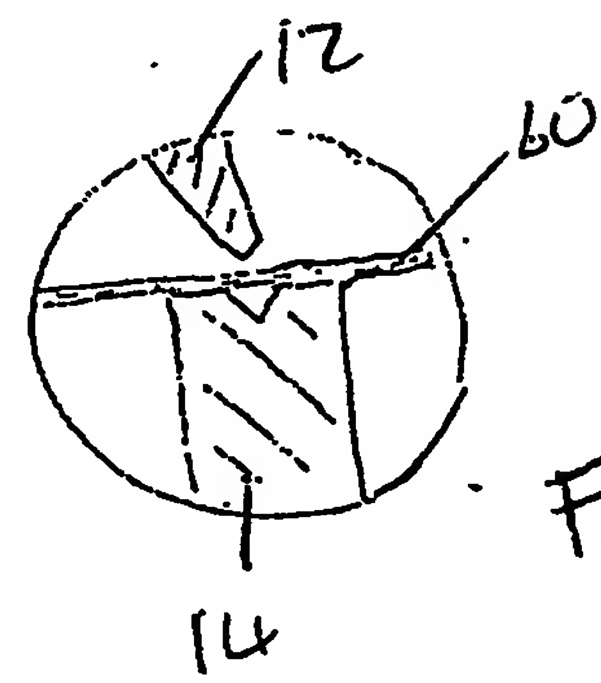


Fig 8c

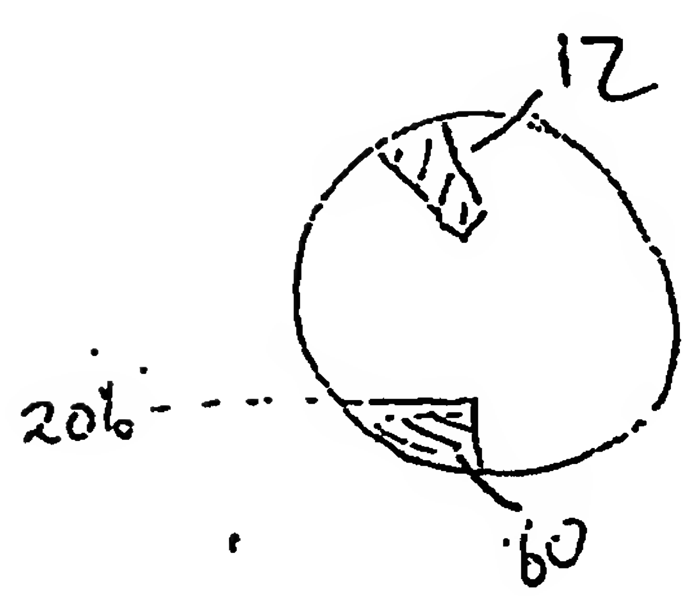


Fig 9a

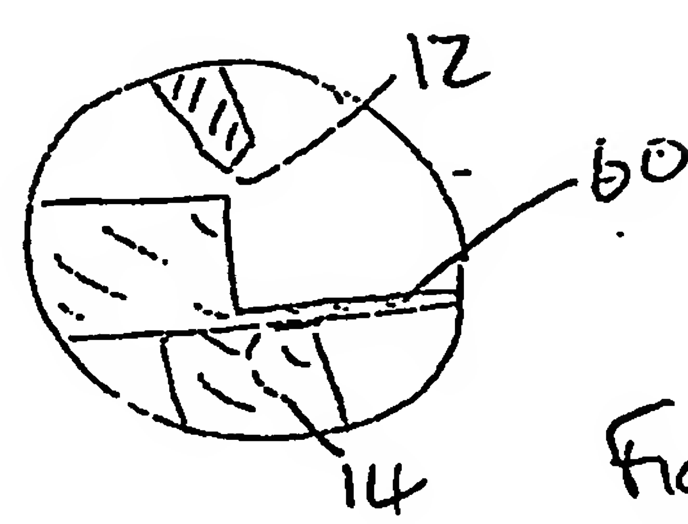


Fig 9b

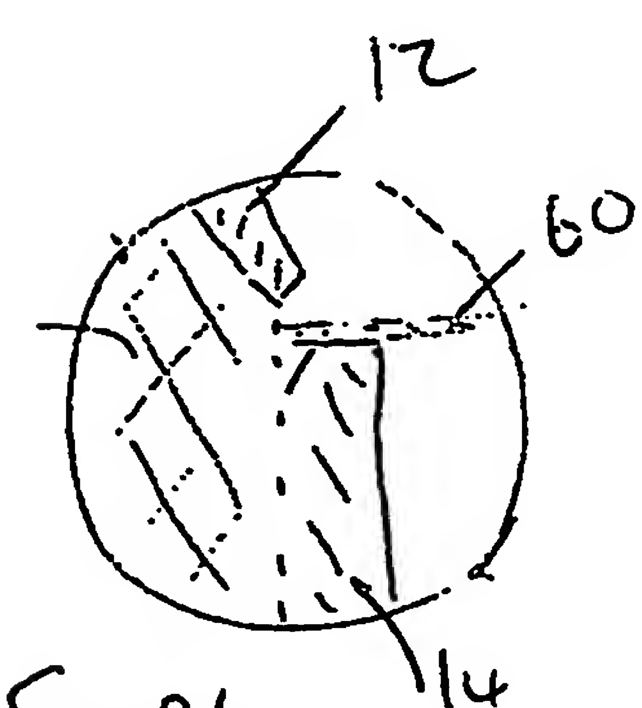


Fig 9b

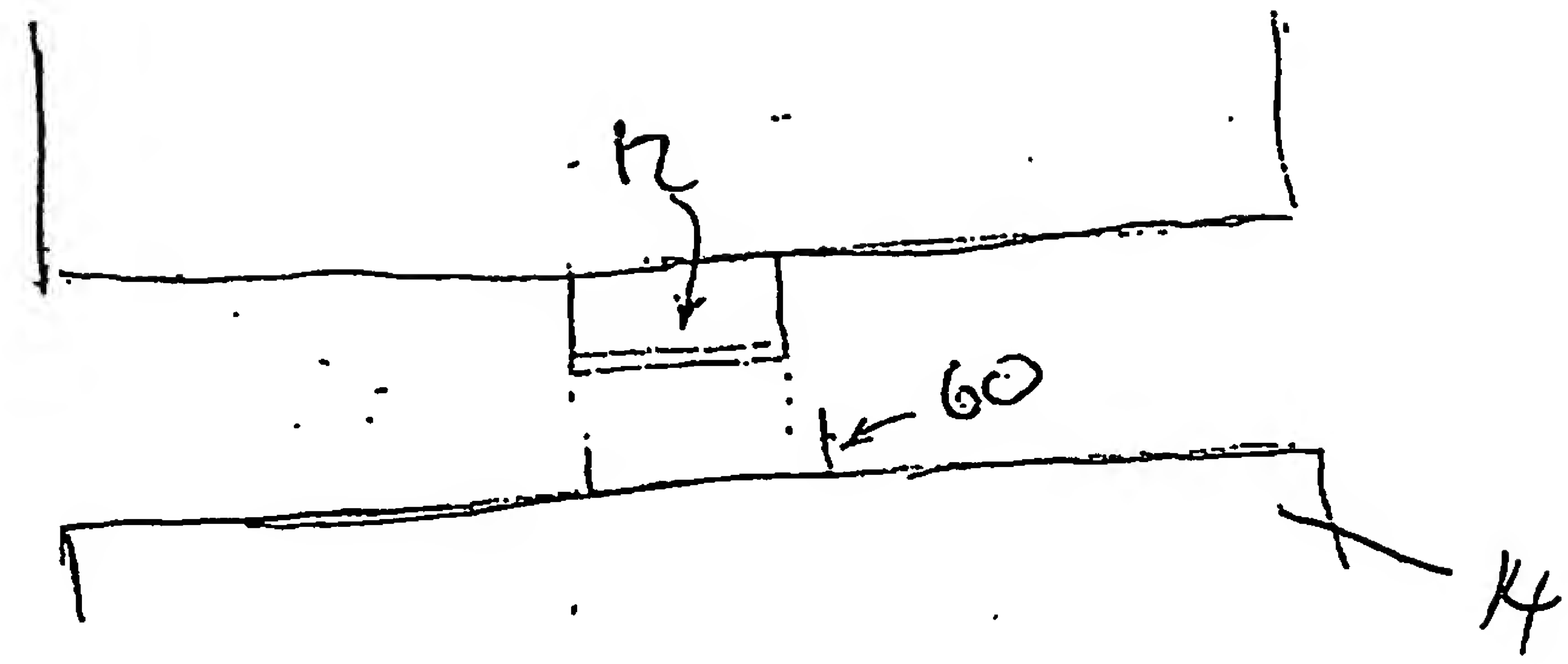


Fig 10

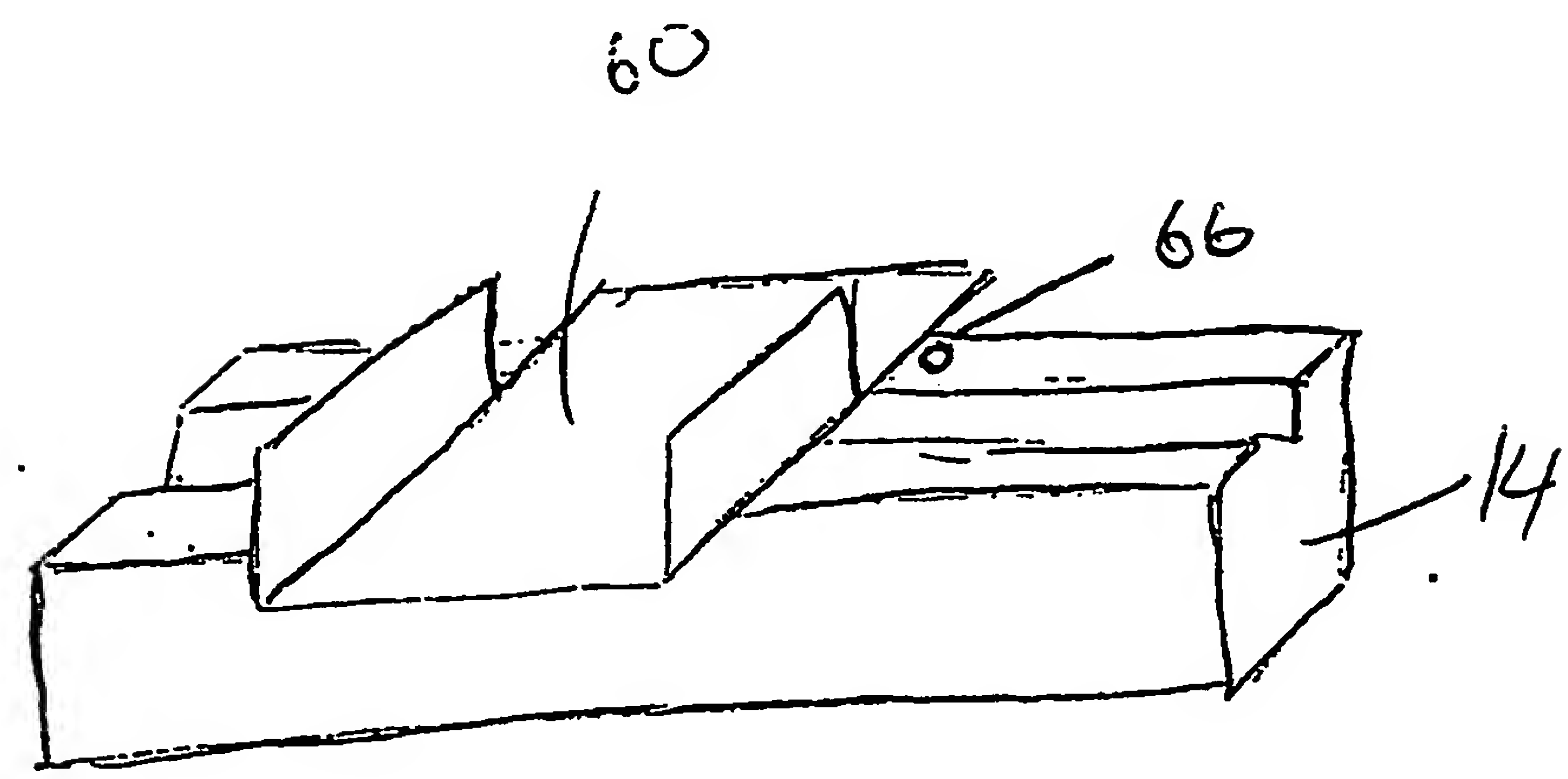
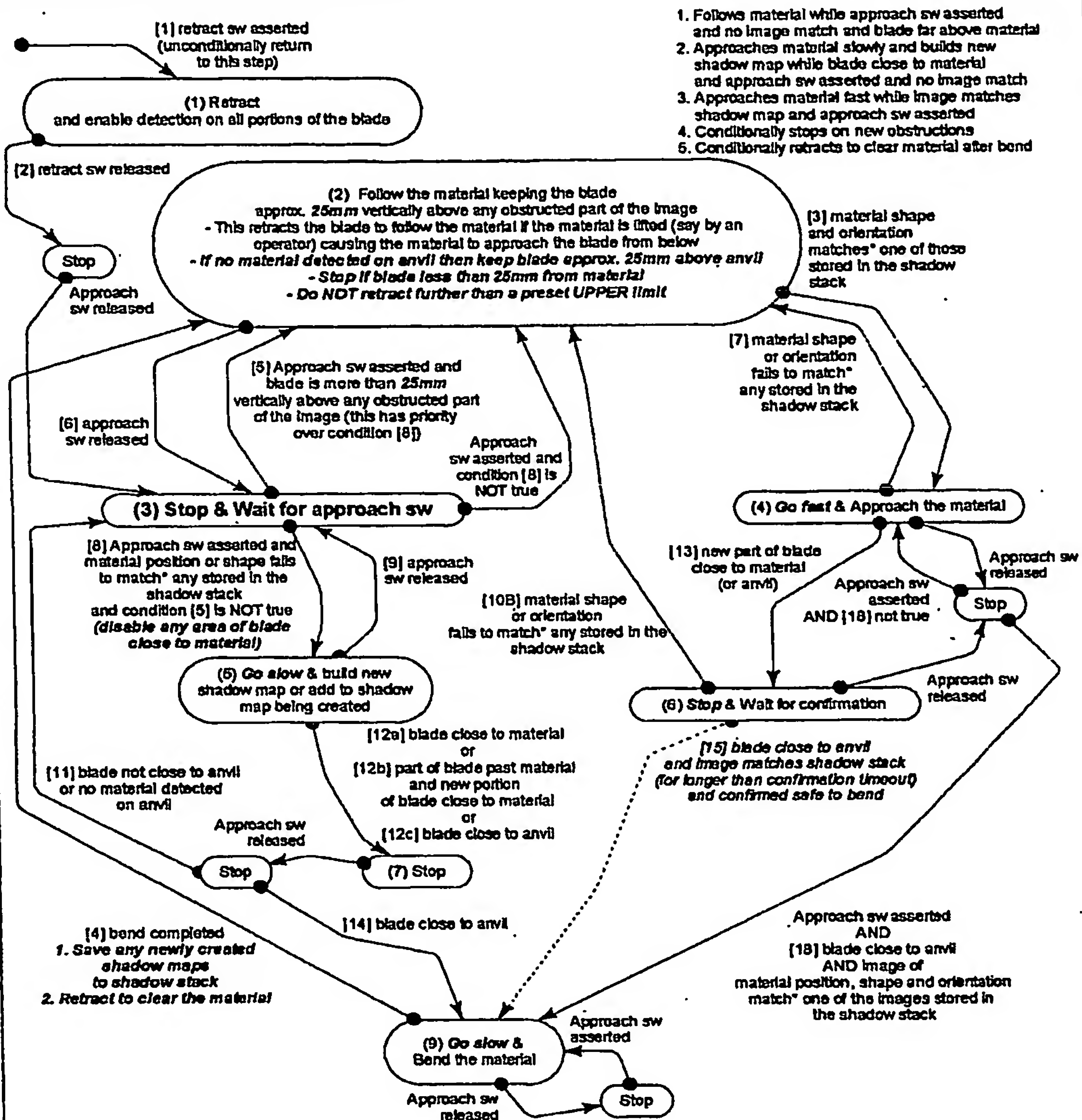


Fig 11

Preferred Control Embodiment #1:

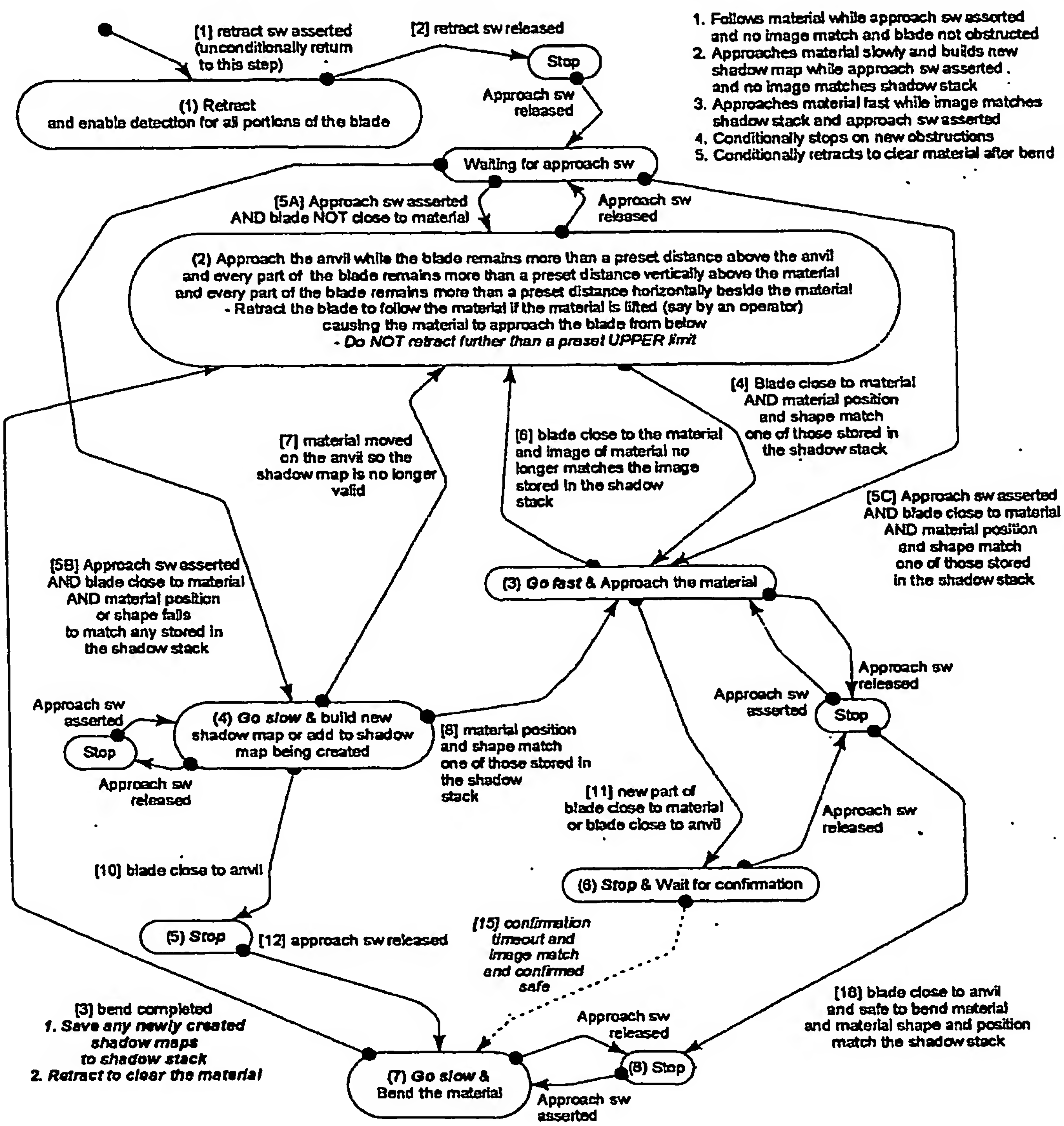


* NOTE1: If an inductive material position sensing means is used then the inductance of the sensor is measured and stored with images when they are stored into the shadow stack When images are compared with the shadow stack, the inductance of the sensor is also compared against the stored value

\# NOTE2: Text in BOLD / ITALICS are given for indication only as situations exist where these may not be entirely appropriate

Fig 12

Follow Material while Approach Asserted



NOTE1: Text in BOLD / ITALICS are given for indication only
Situations exist where these may not be appropriate

Fig 13

Follow Material while Approach Asserted

Preferred Control Embodiment #2:

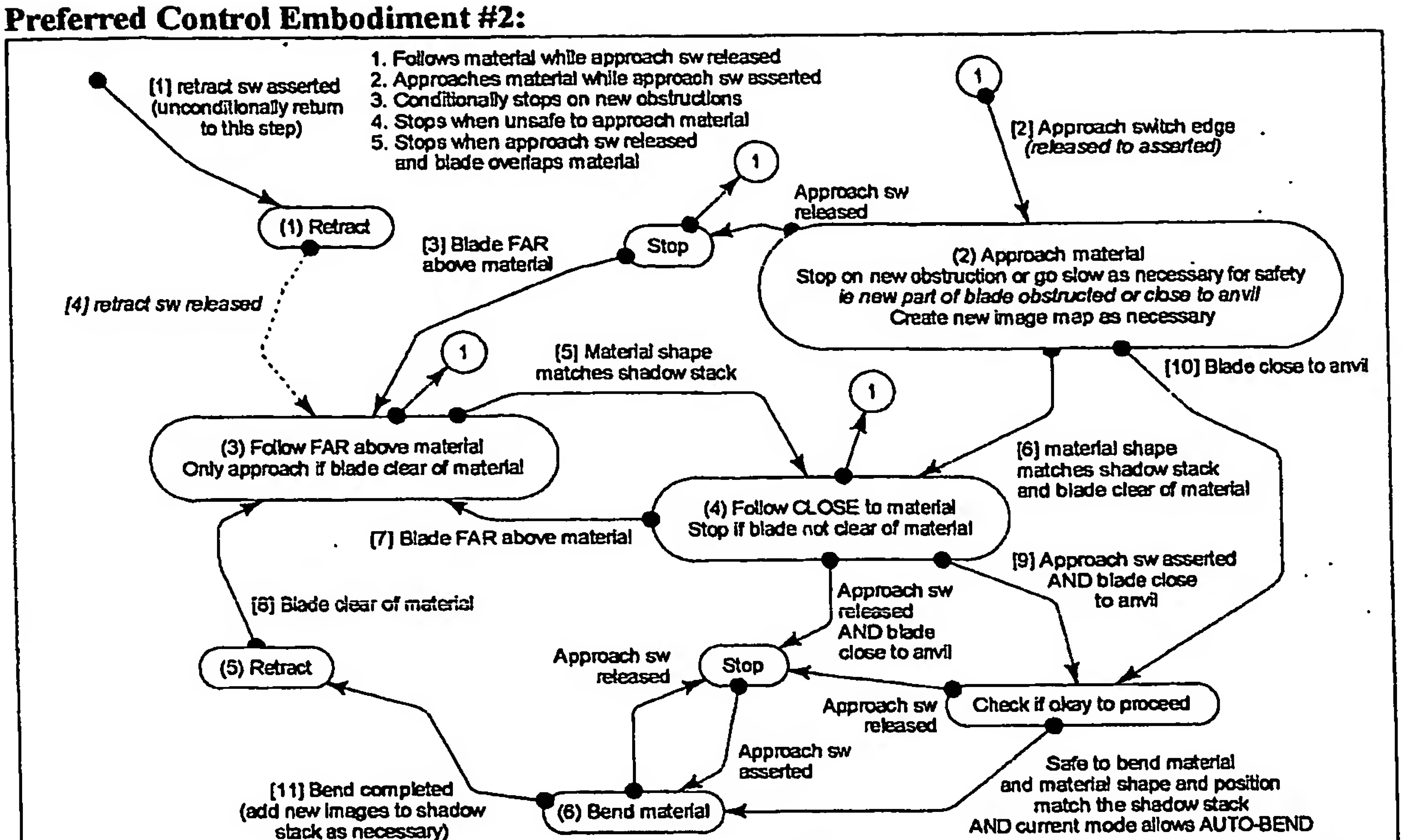


Fig 14 - Auto Approach

Preferred Control Embodiment #3:

In a third preferred embodiment, no memory means is used so the operation is simplified accordingly.

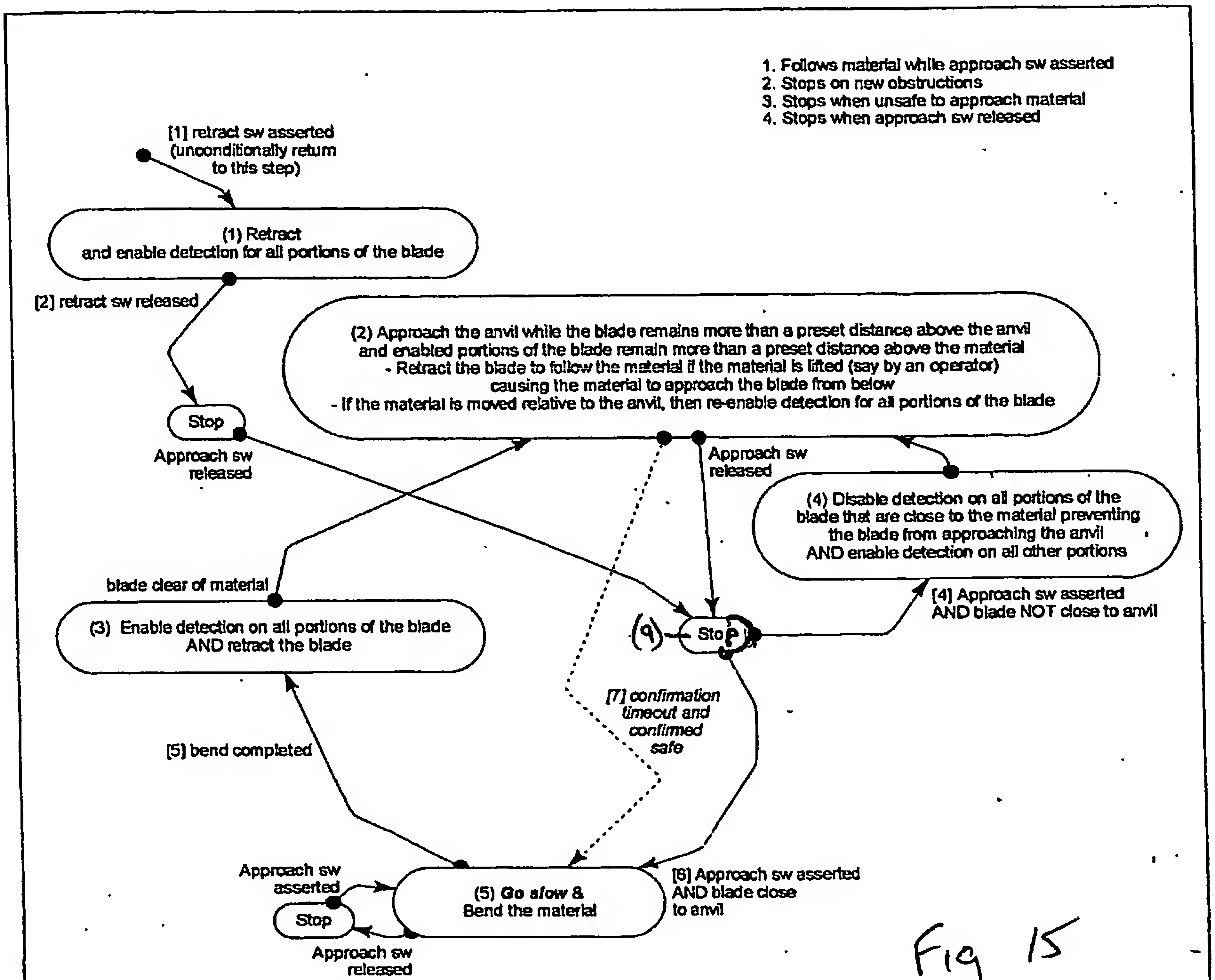


Fig 15

Follow Material while Approach Asserted with No Shadow Stack

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